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Item No.:

Pesticide Registration (PR) Notice 2001-5

NOTICE TO MANUFACTURERS, FORMULATORS, PRODUCERS AND REGISTRANTS OF PESTICIDE PRODUCTS

ATTENTION: Persons Responsible for Registration of Pesticide Products

SUBJECT: Guidance for Pesticide Registrants on Pesticide Resistance Management Labeling

The Office of Pesticide Programs (OPP) of the United States Environmental Protection Agency (EPA) announces purely voluntary pesticide resistance management labeling guidelines based on mode/target site of action for agricultural uses of herbicides, fungicides, bactericides, insecticides, and acaricides. This document provides acceptable schemes of classification of pesticides according to their mode/target site of action (Appendices I-III), a standard format for showing group identification symbols on the end-use product labels, and examples of resistance management labeling in the use directions. These guidelines are the result of a joint effort of the U.S. and Canada under the North American Free Trade Agreement (NAFTA).

I. Scope

The mode/target site of action symbols and pesticide resistance management labeling statements described in this Pesticide Registration (PR) notice are voluntary. This PR Notice is directed to Registrants of herbicide, fungicide, bactericide, insecticide, and acaricide products that are intended for general agricultural use, including both new products and old (existing) products and is not mandatory. EPA does not expect to require the use of this labeling in any individual licensing proceeding. However, EPA believes that this approach to resistance management is sound and would be highly beneficial to pesticide manufacturers and pesticide users. EPA is hopeful that Registrants will embrace this approach and work with EPA to implement it for all relevant products. EPA believes this approach is an important element of international harmonization.

II. Introduction

The United States Environmental Protection Agency (EPA) and the Pest Management Regulatory Agency of Canada (PMRA) are committed to long-term pest resistance management through pesticide resistance management and alternative pest management strategies. Under the auspices of the North American Free Trade Agreement (NAFTA), the U.S. and Canada have joined together to develop and publish guidelines for voluntary pesticide resistance management labeling for implementation in North America. The development of these guidelines is part of the activities of the Risk Reduction Subcommittee of the NAFTA Technical Working Group on Pesticides. A uniform approach across North America will help reduce the development of pest resistance and support joint registration decisions by providing consistency in resistance management labeling being considered for approval in any or all of the NAFTA countries.

Pesticide resistance is defined for the purposes of this document as an heritable and significant decrease in the sensitivity of a pest population to a pesticide that is shown to reduce the field performance of pesticides. Pests covered by this initiative include insects, mites, weeds, and fungi and bacteria which cause plant disease. The management of pesticide resistance development is an important part of sustainable pest management and this, in conjunction with alternative pest management strategies and Integrated Pest Management (IPM) programs, can make significant contributions to reducing risks to humans and the environment. In support of these goals, the purpose of this document is to provide guidance on resistance management labeling based on mode/target site of action to Registrants. A consequence of this PR notice will be to provide guidance to users about pesticide resistance management strategies based on mode/target site of action.

Pesticides are important pest management tools. Many pesticides have gradually lost their effectiveness due to the development of resistance by pests they once controlled. An important pesticide resistance management strategy is to avoid the repeated use of a particular pesticide, or pesticides that have a similar target site of action as the pest control mechanism in the same field. Mode/target site of action refers to the biochemical mechanism by which the pesticide acts on the pest and should not be interpreted to imply that these chemicals share a common mechanism for purposes of cumulative human health risk assessment under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and Federal Food Drug and Cosmetics Act (FFDCA) as amended by the Food Quality and Protection Act of August 3, 1996¹. One pest control strategy is rotating pesticides and/or using tank mixtures or premixes with different mode/target sites of action. This will delay the onset of resistance,

¹Common mechanism of toxicity for purposes of cumulative human health risk assessment under FFDCA is described in detail in EPA's guidance document "Guidance for identifying pesticide chemicals and other substances that have a common mechanism of toxicity" located at <http://www.epa.gov/fedrgstr/EPA-PEST/1999/February/Day-05/6055.pdf>.

as well as slow the development and subsequent buildup of resistance, without resorting to increased rates and frequency of application, and ultimately, will prolong the useful life of many pesticides.

A resistance management strategy should also consider cross-resistance between pesticides with different modes/target sites of action. Pests may develop cross-resistance to pesticides based on mode/target site of action. This voluntary labeling initiative will provide pesticide users with easy access to important information regarding pesticide mode/target site of action, the cornerstone of most resistance management programs.

To ensure consistency in pesticide grouping and labeling, and to contribute to the management of the pesticide resistance problem, the following guidelines have been developed for agricultural uses of herbicides, fungicides, bactericides, insecticides, and acaricides. The following classification schemes are based on mode/target site of action.

III. Presentation and Format of Resistance Management Information on Pesticide Labels

The use of target site of action symbols and pesticide resistance management statements in this PR Notice is voluntary. Canada and Australia have adopted color schemes that are consistent across target site of action groupings. The Canadian system is voluntary and is analogous to the guidelines presented by EPA. The Australian system is mandatory. If the approach described here is used, the following format and presentation are recommended.

A. Mode/Target Site of Action Grouping and Identification Symbol

Herbicides, fungicides, bactericides, insecticides, and acaricides are separately grouped according to their mode/target site of action by various technical/research committees consisting of representatives of the pesticide industry, researchers, extension specialists and regulatory officials. The Agency based its mode/target site of action groupings on those previously defined by the following industry technical committees: Herbicide Resistance Action Committee (HRAC), Fungicide Resistance Action Committee (FRAC), and Insecticide Resistance Action Committee (IRAC). Information on each of these organizations, the mode/target site of action groups, and recommended resistance management strategies may be found at the following web site: <http://www.gcpf.org>. Additional guidance for herbicides was provided by the Weed Science Society of America (WSSA). The WSSA and HRAC have sponsored Dr. Ian Heap to set up a web site dedicated to ongoing surveys of herbicide resistance world-wide: <http://www.weedscience.com>. This web site includes information on identifying mode/target site of action for each herbicide using both the HRAC alphabetic classification system and the WSSA numerical classification system that is currently in use by Canada and will be used by EPA. The target site of action groups plus the identifier numbers for herbicides, fungicides/bactericides, and insecticides/acaricides are located in Appendix I, II and III, respectively.

If used, the target site of action identification symbol should be shown on all end-use product

labels (except products for homeowner/residential uses) in a standard format as outlined below, and should:

1. be located in the upper right quadrant of the front panel surrounded by a black (or suitable color) rectangle, but should not conflict with the required placement of any other front panel element;
2. be in black and on a white background (or other suitable contrasting colors) except the target site of action number(s) which should be white on a black background with a clear white gap (or other suitable contrasting colors) between the target site of action numbers; and
3. include the words "GROUP" and "HERBICIDE" (or "FUNGICIDE" or "INSECTICIDE") in capital letters, and between these words the number(s) representing the target site of action group(s) of each active ingredient(s). Where a product has two or more active ingredients, and these are represented by two or more sites of action, then two or more appropriate target site of action identifier numbers should be used. For products containing an active ingredient that has multiple sites of action, the letter "M" should be used to represent the target site of action group. Alternatively, if sites of action are known, the label should specify each target site of action by the appropriate number.

Example 1: Product containing one active ingredient represented by one target site of action.

GROUP	1	HERBICIDE
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Example 2: Product containing two or more active ingredients represented by two or more target sites of action.

GROUP	1	2	3	HERBICIDES
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Example 3: Pre-mixture of a fungicide and an insecticide.

GROUP	1	FUNGICIDE
GROUP	2	INSECTICIDE

B. Resistance Management Statements

Use of the resistance management statements described below is voluntary. If used, these statements should be included in the general use directions for end-use products (except products for homeowner/residential uses) for the control of weeds, plant pathogens (diseases), insects and mites under the heading "Resistance Management Recommendations." The section "Resistance Management Recommendations" should be segregated under the "General" portion of the "Use Directions" and preferably boxed to distinguish these statements from mandatory statements on the pesticide label.

The examples of standard resistance management labeling statements listed below provide a general framework of actions that have been noted to be useful in mitigating pest resistance and should be used as appropriate. The development and use of specific resistance management strategies and labeling statements should be developed on the basis of scientific data on a product/class specific basis based on the pesticide product/class, crop, and pest(s) combination and the use history for the pesticide and crop/pest(s) combination. These strategies and labeling statements should be included in any product-specific literature. Efforts should be made to include all appropriate active ingredients and products. In addition to known pest resistance to (a) pesticide(s), appropriate resistance management labeling language should be provided for situations in which pest resistance has not occurred to a given pesticide product or to a given pesticide class, but is part of a good pesticide stewardship program to delay the onset of pest resistance.

1. Herbicides

The following general herbicide resistance management labeling statements may be applicable.

"(Name of product) is a Group (target site of action group number) herbicide. Any weed population may contain or develop plants naturally resistant to (name of product) and other Group (target site of action group number) herbicides. Weed species with acquired resistance to Group (target site of action group number) may eventually dominate the weed population if Group (target site of action group number) herbicides are used repeatedly in the same field or in successive years as the primary method of control for targeted species. This may result in partial or total loss of control of those species by (name of product) or other Group (target site of action group number) herbicides."

"To delay herbicide resistance consider:

- Avoiding the consecutive use of (name of product) or other target site of action Group (target site of action group number) herbicides that

have a similar target site of action, on the same weed species.

- Using tank-mixtures or premixes with herbicides from different target site of action Groups as long as the involved products are all registered for the same use, have different sites of action, and are both effective at the tank mix or prepack rate on the weed(s) of concern.
- Basing herbicide use on a comprehensive IPM program.
- Monitoring treated weed populations for loss of field efficacy.
- Contacting your local extension specialist, certified crop advisors, and/or manufacturer for herbicide resistance management and/or integrated weed management recommendations for specific crops and resistant weed biotypes.”

If available to company, consider including:

- “For further information or to report suspected resistance, you may contact (company representatives) at toll free number: _____ or at Internet site: _____.”

Note: The above are general statements for products containing one or more active ingredients from the same target site of action group, e.g., tank mixes and premix products. For products containing two or more active ingredients from different target site of action groups, the following general statements may be applicable. For example:

“(Name of product) is both a Group (target site of action group number) and a Group (target site of action group number) herbicide. Any weed population may contain or develop plants naturally resistant to Group (target site of action group number) and/or Group (target site of action group number) herbicides. Weed species with acquired resistance to Group (target site of action group number) and/or Group (target site of action group number) herbicides may eventually dominate the weed population if Group (target site of action group number) and/or Group (target site of action group number) herbicides are used repeatedly in the same field or in successive years as the primary method of control for targeted species. This may result in partial or total loss of control of those species by (name of product) or other Group (target site of action group number) and/or Group (target site of action group number) herbicides.” [Follow with resistance management

labeling statements.]

2. Fungicides and Bactericides

The following general fungicide/bactericide resistance management labeling statements may be applicable.

“(Name of product) contains a Group (target site of action group number) (fungicide/bactericide). Fungal isolates/bacterial strains with acquired resistance to Group (target site of action group number) may eventually dominate the fungal/bacterial population if Group (target site of action group number) fungicides/bactericides are used repeatedly in the same field or in successive years as the primary method of control for targeted species. This may result in partial or total loss of control of those species by (name of product) or other Group (target site of action group number).”

“To delay fungicide/bactericide resistance consider:

- Avoiding the consecutive use of (name of product) or other target site of action Group (target site of action group number) fungicides/bactericides that have a similar target site of action, on the same pathogens.
- Using tank-mixtures or premixes with fungicide/bactericides from different target site of action Groups as long as the involved products are all registered for the same use and are both effective at the tank mix or prepack rate on the pathogen(s) of concern.
- Basing fungicide/bactericide use on a comprehensive IPM program.
- Monitoring treated fungal/bacterial populations for loss of field efficacy.
- Contacting your local extension specialist, certified crop advisors, and/or manufacturer for fungicide/bactericide resistance management and/or IPM recommendations for specific crops and resistant pathogens.”

If available to company, consider including:

- “For further information or to report suspected resistance, you may contact (company representatives) at toll free number: _____ or at Internet site: _____.”

Note: The above are general statements for products containing one or more active ingredients from the same target site of action group, e.g., tank mixes and premix products. For products containing two or more active ingredients from different target site of action groups, the following general statements may be applicable. For example:

“(Name of product) contains both a Group (target site of action group number) and Group (target site of action group number) fungicide/bactericide. Fungal isolates/bacterial strains with acquired resistance to Group (target site of action group number) and/or Group (target site of action group number) may eventually dominate the fungal/bacterial population if Group (target site of action group number) and/or Group (target site of action group number) fungicides/bactericides are used repeatedly in the same field or in successive years as the primary method of control for targeted species. This may result in partial or total loss of control of those species by (name of product) and/or Group (target site of action group number) and/or Group (target site of action group number) fungicides/bactericides.” [Follow with resistance management labeling statements.]

3. Insecticides and Acaricides

The following general insecticide/acaricide resistance management labeling statements may be applicable.

“(Name of product) contains a Group (target site of action group number) insecticide (or acaricide). Insect/mite biotypes with acquired resistance to Group (target site of action group number) may eventually dominate the insect/mite population if Group (target site of action group number) insecticides/acaricides are used repeatedly in the same field or in successive years as the primary method of control for targeted species. This may result in partial or total loss of control of those species by (name of product) or other Group (target site of action group number).”

“To delay insecticide (or acaricide) resistance consider:

- Avoiding the consecutive use of (name of product) or other group (target site of action group number) insecticides/acaricides that have a similar target site of action, on the same insect/mite species.
- Using tank-mixtures or premixes with insecticides/acaricides from a

different target site of action Group as long as the involved products are all registered for the same use and have different sites of action.

- Basing insecticide/acaricide use on a comprehensive IPM program.
- Monitoring treated insect/mite populations for loss of field efficacy.
- Contacting your local extension specialist, certified crop advisors, and/or manufacturer for insecticide/acaricide resistance management and/or IPM recommendations for the specific site and resistant pest problems.”

If available to company, consider including:

- “For further information or to report suspected resistance, you may contact (company representatives) at toll free number: _____ or at Internet site: _____.”

Note: The above are general statements for products containing one or more active ingredients from the same group, e.g., tank mixes and premix products. For products containing two or more active ingredients from different groups, the following general statements may be applicable. For example:

“(Name of product) contains both a Group (target site of action group number) and Group (target site of action group number) insecticides/acaricides. Insect/mite population(s) with acquired resistance to Group (target site of action group number) and/or Group (target site of action group number) may eventually dominate the insect/mite population if Group (target site of action group number) and/or Group (target site of action group number) insecticides/acaricides are used repeatedly in the same field or in successive years as the primary method of control for targeted species. This may result in partial or total loss of control of those species by (name of product) or Group (target site of action group number) and/or Group (target site of action group number).” [Follow with resistance management labeling statements.]

4. Pesticides of Unspecified Groups or Pesticides Without History of Resistance

Some herbicides, fungicides, bactericides, insecticides, and acaricides have not been assigned to any particular target site of action group, or are not on the lists in this

document because of the lack of clear understanding of their target site of action or the absence of a history of resistance development for the product, e.g., nematicides. Also, in general, herbicides with an unknown target site of action and/or multiple sites of action historically have been less prone to the development of weed resistance.

Registrants are encouraged to establish the appropriate group identifications for their products in consultation with representatives of the pesticide industry, technical working groups such as the WSSA, IRAC, FRAC, HRAC, researchers, extension specialists, crop consultants, and regulatory officials. Appropriate resistance management statements for the product, i.e., herbicides, fungicides, bactericides, insecticides, and/or acaricides, should be developed similar to those described above.

IV. Addition or Changes to Target Site of Action Lists

The pesticide lists will be updated from time to time (approximately annually) to include product names and/or new/revised target site of action classification. This will be done in consultation with WSSA, IRAC, HRAC, and FRAC and other appropriate organizations. Updated lists will be posted on the Office of Pesticide Program's home page. Hard copies will be made available from the Agency upon request.

V. Implementation

The implementation of this program is purely voluntary by the pesticide industry and is part of a NAFTA labeling harmonization effort on pesticide resistance management with Canada. Canada's guidelines, Regulatory Directive DIR99-06, for voluntary pesticide resistance management labeling were finalized, October 6, 1999. Canada has set a target date of January 1, 2004 for implementation of its pesticide resistance management labeling guidelines. As part of the Agency's harmonization efforts on pesticide resistance management labeling with Canada, Registrants are encouraged to add the resistance management grouping symbols and statements to product labels in a similar time frame. Registration and reregistration approval will not be contingent on inclusion of either the resistance management labeling statements or the mode/target site of action classification. However, in view of the importance of resistance management to a long-term pest management strategy, the EPA will evaluate the industry's implementation of resistance management labeling. The process for how to change labels is described in Section VI.

Resistance management strategies are not requirements for the user, even if the product bears resistance management statements or the mode/target site of action classification. Failure to follow the recommended resistance management strategies on the labeling is not regarded by EPA as a misuse of the product.

VI. How to Change Labels

No registrant will be required to add resistance management statements or appropriate mode/target site of action classification to the product label. Because pesticide resistance management is important, though, EPA encourages Registrants to include both the resistance management statements and the mode/target site of action classification on the product label whenever submitting new or revised labeling to the Agency for registration or reregistration. In order to make it easy for Registrants to add resistance management statements and the target site of action classification to their product labels, and because so many products may be affected, EPA will permit the statements and the target site of action classification to be added by notification.

Registrants who wish to add the appropriate mode/target site of action classification and the resistance management statements may do so by notification to the Agency, provided that:

1. The statements as worded and the appropriate mode/target site of action classification as stated in this notice are used. The resistance management statements and mode/target site of action classification system in this notice have been developed in conjunction with international efforts including industry/academic technical working groups, and Registrants are urged to consider adopting it as written.

OR

2. Similarly worded statements are used. EPA recognizes that Registrants may wish to use wording of their own development or more specific resistance management strategies. Therefore, EPA will permit the addition of similarly worded statement also by notification. Wording may be varied to accommodate the needs of the individual products. However, the following information is considered important to user understanding, and EPA strongly encourages Registrants to include the following points in their statements (in addition to the mode/target site of action Group classification on the front panel):

- a. The product is classified in one or more listed mode/target site of action Groups;
- b. The target pest species may develop natural resistance to the pesticide product and resistant species may become dominant in any given field situation if the product is used repeatedly;
- c. If resistance develops, the product may lose effectiveness in controlling the pest species.
- d. Effective resistance management can delay resistance:

Avoid repeated or sequential use of products in the same Group;
Use tank mixes or premixes from a different Group;

Use an effective IPM program;
Monitor [pest, weed, insect, etc.] populations for loss of efficacy;
Contact your extension specialist, certified crop consultant, or manufacturer for the latest resistance management information;
Contact the producer to report loss of efficacy.

EPA emphasizes that the recommended resistance management statements and mode/target site of action Group classification number are not mandatory for users, but provide information and guidance that will benefit users. Registrants are strongly encouraged to use the mode/target site of action classification system and to use a heading such as “Resistance Management Recommendations” and to clearly segregate the information from mandatory use instructions by presentation, such as by boxing the statements. This will ensure that users are fully informed about resistance management, while making clear that compliance is not required.

EPA will work with existing pesticide education efforts that will be used to implement the guidance of this PR notice such as the WSSA extension committee, State Pesticide Applicator Training Programs, federal and state extension programs, IRAC, HRAC, and FRAC to demonstrate how effective resistance management strategies benefit users, the agricultural community, and environmental groups. EPA intends to develop a Fact Sheet about effective resistance management strategies that will provide more extensive information about our efforts.

U.S. Postal Service Deliveries

The following official mailing address must be used for all correspondence or data submissions sent to OPP by mail:

Document Processing Desk (NOTIFICATION), (AMEND), or (APPL), as applicable
Office of Pesticide Programs (7504C)
U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460-0001

Personal/Courier Service Deliveries

The following address must be used for all correspondence or data submissions that are hand-carried or sent by courier service Monday through Friday, from 8:00 AM to 4:30 PM, excluding Federal holidays:

Document Processing Desk (NOTIFICATION), (AMEND), or (APPL), as applicable
Office of Pesticide Programs (7504C)

U.S. Environmental Protection Agency
Room 266A, Crystal Mall 2
1921 Jefferson Davis Highway
Arlington, Virginia 22202

VII. Scope of Policy

This PR Notice provides guidance to EPA, to pesticide Registrants and applicants, and to the public. As a guidance document, this notice is not binding on either EPA or pesticide Registrants, and EPA may depart from the guidance provided in individual circumstances and without notice. For the matters covered by this particular PR Notice, EPA does not expect to require that any Registrant adopt the labeling set forth here as part of any individual licensing decision or action. However, if any Registrant seeks to use the language set forth here in the manner and circumstances described here, EPA does generally expect to find such language acceptable in any licensing proceeding. However, EPA believes that the approach to resistance management described in this PR Notice is sound and would be highly beneficial to pesticide manufacturers and pesticide users. EPA is hopeful that Registrants will embrace this approach and work with EPA to implement it for all relevant products. EPA believes this approach is an important element of international harmonization.

VIII. For Further Information

If you have general questions about this PR Notice, or about resistance management labeling, please contact:

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If you have specific product questions, contact the Labeling Team (703-308-9068/69), the appropriate Product Manager (Registration Division and Antimicrobial Division) or Regulatory Action Leader (Biopesticides and Pollution Prevention Division) for your product.

Marcia E. Mulkey, Director
Office of Pesticide Programs

Attachments:

Appendix I: Herbicide Groups Based on Target Site of Action

Appendix II: Fungicide/Bactericide Groups Based on Activity Group/Target Site of Action

Appendix III: Insecticide and Acaricide Groups Based on Target Site of Action

Appendix I: Herbicide Groups Based on Target Site of Action¹

GROUP	TARGET SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
1	Inhibitors of acetyl CoA carboxylase (ACCase)	Aryloxyphenoxy propionates	clodinafop-propargyl
			diclofop-methyl
			fenoxaprop-ethyl
			fenoxaprop-p-ethyl
			fluazifop-p-butyl
			fluazifop-butyl
			quizalofop-ethyl
			quizalofop-p-ethyl
		Cyclohexanediones	clethodim
			sethoxydim
			tralkoxydim
2	Inhibition of acetolactate synthase (ALS) and also called aceto-hydroxyacid synthase (AHAS)	Sulfonylureas	bensulfuron
			chlorimuron
			chlorsulfuron
			ethametsulfuron-methyl
			halosulfuron-methyl
			metsulfuron-methyl
			nicosulfuron
			primisulfuron
			prosulfuron
			rimsulfuron
			sulfometuron
			sulfosulfuron
			thifensulfuron-methyl
			triasulfuron
			tribenuron-methyl
			triflusalofuron-methyl
		Imidazolinones	imazamethabenz
			imazamox
			imazapyr
			imazaquin

Appendix

GROUP	TARGET SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
			imazethapyr
		Pyrimidinylthio-benzoate	pyrithiobac sodium
		Triazolopyrimidine	flumetsulam
			cloransulam-methyl
3	Microtubule assembly inhibitors	Dinitroanilines	benefin
			benfluralin
			ethalfluralin
			oryzalin
			pendimethalin
			trifluralin
		Pyridazine	dithiopyr
			thiazopyr
		Benzoic acid	chlorthal-dimethyl (DCPA)
4	Synthetic auxins (action like indoleacetic acid)	Phenoxy carboxylic acids	2,4-D
			2,4-DB
			dichlorprop (2,4-DP)
			MCPA
			MCPB
			mecoprop (MCP)
		Benzoic acids	dicamba
		Pyridine carboxylic acids	clopyralid
			fluroxypyr
			picloram
			triclopyr
		Quinoline carboxylic acid	quinclorac
	Inhibition of IAA action	Semicarbazone	diflufenzopyr
5	Inhibitors of photosynthesis at photosystem II Site A	Triazines	ametryn
			atrazine
			cyanazine
			prometon

GROUP	TARGET SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
			prometryn
			propazine
			simazine
		Triazinones	hexazinone
			metribuzin
		Uracils	bromacil
			terbacil
		Pyridazinone	pyrazon
		Phenylcarbamates	desmedipham
			phenmedipham
6	Similar to group 5, but different binding behavior	Nitriles	bromoxynil
			ioxynil
		Benzothiadiazoles	bentazon
		Phenylpyridazine	pyridate
7	Inhibitors of photosynthesis at photosystem II Site B	Ureas	diuron
			fluometuron
			linuron
			metobromuron
			monolinuron
			siduron
			tebuthiuron
		Amide	propanil
8	Inhibition of lipid synthesis - not ACCase inhibition	Thiocarbamates	butylate
			cycloate
			EPTC
			molinate
			pebulate
			thiobencarb
			triallate
			vernolate
		Benzofuran	bensulide

Appendix

GROUP	TARGET SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
	Unknown	None generally accepted	difenzoquat
9	Inhibitors of EPSP synthase	Glycines	glyphosate sulfosate
10	Inhibitors of glutamine synthetase	Phosphinic acids	glufosinate-ammonium
11	Bleaching: Inhibitors of carotenoid biosynthesis (unknown target)	Triazole	amitrole
12	Bleaching: Inhibitors of carotenoid biosynthesis at the phytoene desaturase step (PDS)	Pyridazinone	norflurazon
		Nicotinanilide	diflufenican
		Others	fluridone
			flurochloridone
			flurtamone
13	Bleaching: Inhibition of all diterpenes	Isoxazolidinone	clomazone
14	Inhibitors of protoporphyrinogen oxidase (PPO)	Diphenylethers	acifluorfen
			fomesafen
			lactofen
			oxyfluorfen
		N-phenyl-phthalimides	fluthiacet-methyl (thiadiazole)
			flumiclorac-pentyl
		Oxadiazole	oxadiazon
		Triazolinone	carfentrazone-ethyl
			sulfentrazone
15	Inhibition of cell division	Chloroacetamides	acetochlor
			alachlor
			butachlor
			metolachlor
			s-metolachlor
			pronamide (propyzamid)
			propachlor
			demethenamid
		Acetamides	diphenamid
			napropamide
		Benzthiozole	mefenacet

GROUP	TARGET SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT
		Oxyacetamides	flufenacet
16	Unknown	Carbonic acid	ethofumesate
17	Unknown	Organoarsenicals	Arsenic, present as disodium salt of methanearsonic acid (DSMA)
			Arsenic, present as monosodium salt of methanearsonic acid (MSMA)
18	Inhibits DHP (dihydropteroate) synthase step	Carbamate	asulam
19	Inhibits indoleacetic acid action	Phthalamate	naptalam
20	Inhibits cell wall synthesis Site A	Nitrile	dichlobenil
21	Inhibits cell wall synthesis Site B	Benzamide	isoxaben
22	Photosystem I electron diverters	Bipyridyliums	diquat
			paraquat
23	Inhibitors of mitosis	Carbamates	chlorpropham
			propham
24	Uncoupling (ATP) membrane disruptors	Dinitrophenol	dinoseb ²
25	Unknown	Arylamino-propionic acid	flamprop-methyl
26	Inhibition of lipid synthesis - not ACCase inhibition	Chlorocarbonic acid	trichloroacetic acid (TCA)
27	Unknown	Cineole	bromobutide
			cinmethylin
			dymron
			flupoxam
28	Bleaching inhibition of 4-hydroxy-phenyl-pyruvate-dioxygenase (4-HPPD)	Isoxazole	isoxaflutole
		Pyrazole	pyrazolynate
		Triketone	sulcotrione

1. This list is based on the Herbicide Classification of the Weed Science Society of America (WSSA) (*Weed Technology*, 1997, 11:384-393) in consultation with the specialist technical working group, Herbicide Resistance Action Committee (HRAC) of the Global Crop Protection Federation (GCPF) (see <http://www.gcpf.org>). HRAC and WSSA both have mode of action classification systems for herbicides. The HRAC uses an alphabetic classification system and the WSSA uses a numerical classification system. See <http://www.weedscience.com> for a side-by-side comparison. Microbial herbicides are not included. In general, herbicides with an unknown target site of action and/or multiple sites of action, have been less

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prone to the development of weed resistance. Herbicides with known resistance world-wide are identified on the following web site: <http://www.weedscience.com>.

2. There are no active registered uses for dinoseb in the U.S.

Appendix II: Fungicide/Bactericide Groups Based on Activity Group/Target Site of Action¹

GROUP	ACTIVITY GROUP/ TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
1	Inhibition of tubulin formation	Benzimidazoles	benomyl
			carbendazim
			fuberidazole
			thiabendazole
			thiophanate
			thiophanate-methyl
2	Affect cell division, DNA & RNA synthesis, & metabolism	Dicarboximides	iprodione
			procymidone
			vinclozolin
3	DMI (Demethylation Inhibitor): Inhibition of sterol synthesis	Imidazoles	imazalil
			perfurazoate
			prochloraz
			triflumizole
		Piperazine	triforine ²
		Pyridine	pyrifenox
		Pyrimidines	fenarimol
			nuarimol
		Triazoles (includes conazoles)	bitertanol
			bromuconazole
			cyproconazole
			diclobutrazol
			difenoconazole
			diniconazole
			epoxiconazole
			fenbuconazole
			fluquinconazole
			flusilazole
			flutriafol
			hexaconazole
			metconazole
			myclobutanil

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GROUP	ACTIVITY GROUP/ TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
			paclobutrazol
			penconazole
			propiconazole
			tebuconazole
			tetraconazole
			triadimefon
			triadimenol
			triticonazole
4	Phenylamides- Affect RNA synthesis	Acylamines	benalaxyl
			furalaxyl
			metalaxyl
			<i>m</i> -metalaxyl
		Oxazolidinones	oxadixyl
		Butyrolactones	ofurace
5	Morpholines	Morpholines	aldimorph
			fenpropimorph
			tridemorph
		Piperidine	fenpropidin
		Spiroketalamine	spiroxamine
6	Phosphorothiolate	Organophosphorous	edifenphos
			iprobenfos (IBP)
			isoprothiolane
			pyrazophos
7	Oxathiin: Affect mitochondrial transport chain	Anilide (Oxathiin)	bendodanil
			carboxin
			flutolanil
			mepronil
			oxycarboxin
8	Hydroxyprimidine	Pyrimidinol	bupirimate
			dimethirimol
			ethirimol

GROUP	ACTIVITY GROUP/ TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
9	Anilinopyrimidine	Anilinopyrimidine	cyprodinil
			mepanipyrim
			pyrimethanil
10	N-Phenyl-carbamates	Diethofencarb	diethofencarb
11	Quinone Outside Inhibitors (QOI)	Strobilurins:	azoxystrobin
		Methoxyacrylate	trifloxystrobin
		Oximinioacetate	kresoxim-methyl
		Non-Strobilurins:	famoxadone
		Oxazolidinedione	
		Imidazolinone	fenamidone
12	Phenylpyrroles	Phenylpyrroles	fenpiclonil
			fludioxonil
13	Quinolines	Quinoline	quinoxifen
14	Aromatic hydrocarbons	Chlorophenyls	chloroneb
			dicloran (DCNA)
			quintozene
			tecnazene
			tolclofos-methyl
			biphenyl
			etridiazole
15	Cinnamic acids	Cinnamic acid	dimethomorph
16	Melanin Biosynthesis Inhibitors (MBI)	Reductase inhibitors	fthalide
			pyroquilon
			tricyclazole
		Dehydratase inhibitor	carpropamid
17	Hydroxyanilide	Hydroxyanilide	fenhexamid
18	Antibiotics		oxytetracycline
			streptomycin
19	Polyoxins		polyoxin
20	Phenylurea		pencycuron

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GROUP	ACTIVITY GROUP/ TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
21	Plant host defense inducers	Benzothiadiazole (BTH)	acibenzolar-S-methyl
			carpropamid
			fosetyl-aluminum
			probenazole
U ³	Unknown Miscellaneous	Amino acid amide	iprovalicarb
		Carbamate	iodocarb
			propamocarb
		Cyano-acetamide oxime	cymoxanil
		Organotins	tri-phenyl tins
			dinocap
			fenfuram
M ⁴	Multi-site activity	Phosphonates	fosetyl-aluminum
			phosphorous acid
		Inorganics	arsenates
			copper (plus salts)
			sulphur
		Dithiocarbamates and relatives	ferbam
			mancozeb
			maneb
			metiram
			propineb
			thiram
			zineb
			ziram
		Chloroalkythios	captafol
			captan
			folpet
		Chloronitrile	chlorothalonil
		Sulphamides	dichlofluanid
			tolyfluanid
		Guanidines	dodine
			guazatine

GROUP	ACTIVITY GROUP/ TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
			iminoctadine
		Anilazine	anilazine
		Quinone	dithianon
		Phenylpyridinamine	fluazinam

1. This list is based on the fungicide listing compiled by the Fungicide Resistance Action Committee (FRAC). FRAC is a specialist technical working group of the Global Crop Protection Federation (GCPF) (see <http://www.gcpf.org>). Microbial fungicides, e.g. *Bacillus subtilis*, or *Agrobacterium radiobacter* K84 and K1026, are not included.
2. There are no active registered uses for triforine in the U.S.
3. The Unknown group, designated by symbol "U," comprises a set of miscellaneous compounds for which that biochemical mode of action may or may not be known, but are not able to placed with certainty in any other groupings.
4. The Multi-site activity grouping, designated by symbol "M," comprises a collection of various chemicals that act as general toxophores with several sites of action. These sites may differ between group members.

Appendix III: Insecticide and Acaricide Groups Based on Target Site of Action¹

GROUP	TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
1A ²	<i>Acetyl choline esterase inhibitors</i> Inhibition of the enzyme acetylcholinesterase, interrupting the transmission of nerve impulses.	Carbamates	aldicarb
			aminocarb
			bendiocarb
			carbaryl
			carbofuran
			formetanate hydrochloride
			methiocarb
			methomyl
			oxamyl
			pirimicarb
			propoxur
1B ²		Organophosphates	acephate
			azamethiphos
			azinphos-methyl
			chlorfenvinphos
			chlorpyrifos
			coumaphos
			diazinon
			dichlorvos/DDVP
			dicrotophos
			dimethoate
			disulfoton
			ethion
			fenitrothion
			fensulfothion
			fenthion
			fonofos
			malathion
			methamidophos
			methidathion
			naled
			oxydemeton-methyl

GROUP	TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
			parathion
			phorate
			phosalone
			phosmet
			pyrazophos
			sulfotep
			tebupirimfos
			temephos
			terbufos
			tetrachlorvinphos
			trichlorfon
2A ²	<i>GABA-gated chloride channel antagonists:</i> Interferes with GABA receptors of insect neurons, leading to repetitive nervous discharges	Chlorinated Cyclodienes	endosulfan
			lindane
			methoxychlor
2B ²	<i>GABA-gated chloride channel antagonists:</i> Interferes with GABA receptors of insect neurons, leading to repetitive nervous discharges-fiprole site.	Phenylpyrazoles	fipronil
3	<i>Sodium channel modulators:</i> Acts as an axonic poison by interfering with the sodium channels of both the peripheral and central nervous system stimulating repetitive nervous discharges, leading to paralysis.	Synthetic Pyrethroids	allethrin
			<i>d-cis-trans</i> allethrin
			<i>d-trans</i> allethrin
			cyfluthrin
			<i>beta</i> -cyfluthrin
			<i>lambda</i> -cyhalothrin
			cypermethrin
			<i>alpha</i> -cypermethrin
			<i>beta</i> -cypermethrin
			<i>theta</i> -cypermethrin
			<i>zeta</i> -cypermethrin
			deltamethrin
			fenpropathrin
			fenvalerate

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GROUP	TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
			flucythrinate
			<i>tau</i> -fluvalinate
			permethrin
			resmethrin
			tefluthrin
			tetramethrin
			<i>d</i> -tetramethrin
			Pyrethrins
4A ²	<i>Acetylcholine receptor agonists/antagonists</i> : Binds to nicotinic acetylcholine receptor, disrupting nerve transmission	Chloronicotines (Nitroguanidines)	imidacloprid
4B ²			nicotine
4C ²			cartap
			bensultap
5	<i>Acetylcholine receptor modulators</i> : Induces acetylcholine-like activity	Spinosyns	spinosyns
6	<i>Chloride channel activators</i> : Interferes with the GABA nerve receptor of insects.	Avermectin	abamectin
			emamectin benzoate
		Milbemycin	milbemycin
7A ²	<i>Juvenile hormone mimics (Insect growth regulator)</i> : Mimic juvenile hormones which prevent moulting from the larval to the adult stage.	Juvenile hormone analogues	fenoxycarb
7B ²			hydroprene
7C ²			methoprene
7D ²			pyriproxifen
8A ²	<i>Unknown or Non- specific target site of action (fumigants)</i>	Fumigant	methyl bromide
8B ²			aluminum phosphide
9A ²	<i>Compounds of unknown or non-specific target site of action (feeding disrupters)</i>	Feeding Disruptors	cryolite
9B ²			pymetrozine
10	<i>Compounds of unknown or non-specific target site of action (mite growth inhibitors)</i>	Mite Growth Inhibitors (Ovicide)	clofentezine
			hexythiazox
11A1 ^{2&3}	<i>Microbial disruptors of insect midgut membranes (includes Cry proteins expressed in transgenic plants)</i> Organism has protein inclusions that are released in the gut of the target pest resulting in gut paralysis and a cessation of feeding.	Bt Microbials (Biological insecticide/larvicide) - Dipteran specific - <i>Bacillus thuringiensis</i> var. <i>israelensis</i>	<i>Bacillus thuringiensis</i> subsp. <i>israelensis</i> strain

GROUP	TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
11A ^{2&3}		Bt Microbials (Biological insecticide/larvicide) - Dipteran specific - <i>Bacillus sphaericus</i>	<i>Bacillus sphaericus</i> strain
11B1 ^{2&3}		Bt Microbials (Biological insecticide/larvicide) - Lepidopteran specific - <i>Bacillus thuringiensis</i> var. <i>aizawai</i>	<i>Bacillus thuringiensis aizawai</i> strain
			<i>Bacillus thuringiensis. aizawai</i> , encapsulated delta endotoxin
11B2 ^{2&3}		Bt Microbials (Biological insecticide/larvicide) - Lepidopteran specific - <i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	<i>Bacillus thuringiensis kurstaki</i> strain
			<i>Bacillus thuringiensis kurstaki</i> encapsulated delta endotoxin
11C ^{2&3}		Bt Microbials (Biological insecticide/larvicide) - Coleopteran specific	<i>Bacillus thuringiensis tenebrionis</i>
			<i>Bacillus thuringiensis tenebrionis</i> encapsulated delta endotoxin
12A ²	<i>Inhibition of oxidative phosphorylation at the site of dinitrophenol uncoupling (disrupt ATP formation)</i>	Organotin miticide	diafenthiuron
12B ²			fenbutatin oxide
13	<i>Uncoupler of oxidative phosphorylation (disrupt H proton gradient formation)</i>	Pyrrole compound (Broad spectrum contact and stomach poison)	chorfenapyr ⁴
14	<i>Inhibit magnesium- stimulated ATPase</i>	Sulfite ester miticide	propargite
15	<i>Inhibit chitin biosynthesis</i>	Substituted benzoylurea	diflubenzuron
16	<i>Inhibit chitin biosynthesis type 1 - Homopteran</i>	Thiadiazine	buprofezin
17	<i>Inhibit chitin biosynthesis type 2- Dipteran</i>	Triazine	cyromazine
18	<i>Ecdysone agonist/disruptor</i> Disrupts insect molting by antagonizing the insect hormone ecdysone	Benzoic acid hydrazide	tebufenozide
19	<i>Octopaminergic agonist</i>	Triazapentadiene	amitraz
20	<i>Site II electron transport inhibitors</i>	None	dicofol
			hydramethylnon
21	<i>Site I electron transport inhibitors</i>	Botanical	rotenone
		Pyridazinone	pyridaben

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GROUP	TARGET SITE OF ACTION	CHEMICAL GROUP	ACTIVE INGREDIENT
22	<i>Voltage dependent sodium channel blocker</i>	Oxadiazine	indoxacarb

1. The classification scheme was developed in consultation with the Insecticide Resistance Action Committee (IRAC) (see <http://www.gcpf.org>). IRAC is a specialist technical working group of the Global Crop Protection Federation (GCPF). It is recognized that resistance of insects and mites to insecticides and acaricides can also result from enhanced metabolism, reduced penetration or behavioral changes that are not linked to any target site of action classification, but are specific for individual chemicals or chemical groups. All members of a class may not be cross-resistant based merely on mode/target site of action. Most biological insecticides are not included in this Appendix because they are thought not to pose as great a concern for resistance development. Microbial products involving Cry delta-endotoxins from *Bacillus* sp. are included as well as certain biochemical products.
2. Not all members of this class have been shown to be cross-resistant. Different resistance mechanisms that are not linked to target site of action, such as enhanced metabolism, are common for this group of chemicals. Alternation of compounds from different subgroups within this class may be an acceptable part of an integrated pest management program.
3. Products containing multiple toxins would be differentiated from those containing single toxins only. This would be done by adding a suffix of “m” for multiple toxin products and “s” for single toxin products. Products containing spores would be differentiated from those without spores by adding “+” for spore-containing products and “-” for those products which do not contain spores. For example, *B. thuringiensis* subsp. *kurstaki* product containing multiple toxins and spores could be designated as Group 11Dm+, while the same product without spores and expressing only one toxin would be designated as Group 11Ds-.
4. There are no U.S. registered uses of chlorfenapyr.